DESIGN AND IMPLEMENTATION OF A DICOM PACS WITH SECURE ACCESS VIA INTERNET

J.Pereira [1],A.Lamelo [1],J.M.Vázquez-Naya [1],M. Fernández [1],J.M. López-Gestal [2], J. Teijero [1],A. Pazos [3]

[1] Medical and Diagnostic Radiological Image Laboratory, A Coruna University. Spain.
[2] Information Systems Unit. Modelo Hospital, A Coruna. Spain
[3] Artificial Neural Networks and Adaptive Systems Laboratory (RNASA//GIB). Department of Information and Communications Technology, A Coruna University. Spain

Abstract: **Among the last new developments in the field of teleradiology, a new system of telediagnostic which allows the remote transmission of digital images via Internetis prevailing. These communications have to be made through mechanisms that guarantee the confidentiality and the integrity of the clinical data, as well as the authenticity of the transmitter. This system is, in many cases, the only way to diagnose the patient pathology in emergency rooms with no radiologist on call.**
Access to the medical data from any computer is possible through the implantation of a picture archiving and communication system (PACS) [1] with direct acquisition from DICOM equipment and Web technology. So, the radiologist with a computer conneted to the WWW (from inside or outside the hospital) has access to the clinical histories and images.
Free distribution software (Apache-PHP-MySQL) and PC platforms in WinNT environment has been used. All the medical imaging equipment of a medium size hospital has been connected to he system, integrating them with the medical history data. Restricted access based on privileges were design to to make reports or only to consult data.
Keywords: **PACS, WEB, DICOM, SSL.**

I. INTRODUCTION

Digital or digitalized diagnostic medical images (Computed Tomography (CT), Digital Subtraction Angiography (DSA), Nuclear Medicine (NM), Magnetic Resonance Image (MRI), Ultrasounds (US) and the Computed Radiography (CR)) allowed the development of the Picture Archiving Communications System (PACS). The increment in implantation of PACS in hospitals is due to the unstoppable advance of the technologies of the information and the reduction of the costs of digital storage systems.

The possibility of a secure access to databases allows the radiologists to make reports from a remote point.

In the present paper, we present an Internet connected PACS for a medium size hospital, which we have called SINFIM (Sistema de INFormación de Imágenes Médicas).

This system permits the automatic acquisition of DICOM images [2] [3] and the access to all the information from any equipment with a web browser and connected to Internet. This characteristic implies the use of security mechanisms, as much for restrict the accesses (identification and authentication of the users) as for a secure communication (encrypted transmissions).

There are several studies [4] [5] [6] [7] [8] using PACS with Web technology and different software tools. No one of this already design systems fits in our requirements: hardware platforms used, price of the software, no automatic system of images acquisition is reported, high costs of maintenance, technological difficulties of implantation or non-existence of user profiles.

Before implanting a PACS in a hospital environment, the convenience of acquiring a completely commercial solution [9] [10] or developing a system adapted to the existing RIS has to be analysed. It´s important to employ standards to obtain a system as open as possible. At the time of analysing this type of technological implantations, the determinant total price is measured by the duration and the cycle of life, as well as the functional benefits facing the competitors and not by the initial payments.

There are several papers about succeded implantation of PACS [11] [12] [13] we followed as valid models in our study.

II. METHODOLOGY

An structure of functional modules for the design of the Information System has been used (fig. 1).

A. Hardware

A PC with Pentium III – 1 Ghz processor, 512 Mb RAM and two 18-Gb UW-SCSI discs in mirror for the operating system has been used as server. For disc array storage we chose a box with capacity for five 18-Gb discs UW-SCSI, each one connected to the server by a RAID 5 Adaptec.

B. Software

Web server: Apache v.1.3.12 [14], free distribution and the most used in Internet [15].

DBMS: MySQL, a free distribution database engine with a spread use through Internet [16].

Web-DB link: PHP4 [17]. It is a free distribution software to develop dynamic HTML pages with access to the data stored in a database.

The performance and working tests were made using navigator Microsoft Internet Explorer 5.5.

Interconnected equipment and with access to the PACS

TAC: GE ProSpeed SX Power

RMN: GE Signa Contour 0,5T

Remote X-ray system: Siemens Siregraf CF

Digital Radiology: AGF A ADC SOLO

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Design and Implementation of A DICOM PACS With Secure Access Via Internet	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Medical and Diagnostic Radiological Image Laboratory A Coruna University, Spain	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
In Supplementary notes put: Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
4

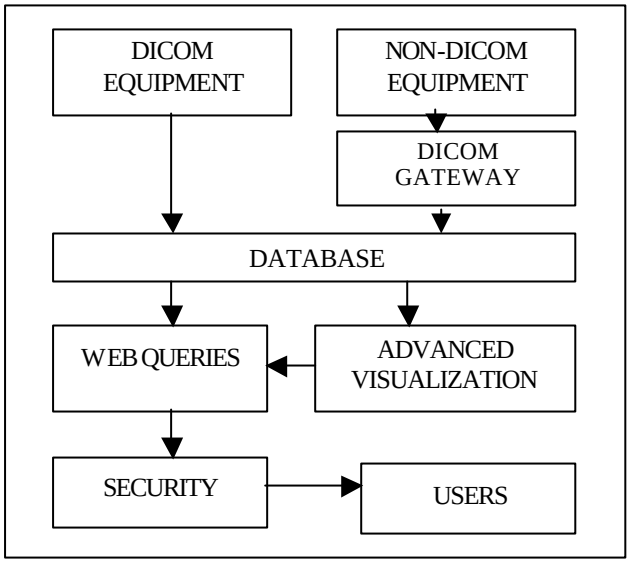

Fig. 1. Functional diagram of the system

C. Modules design

a) Acquisition of the images

It has been developed an automatic acquisition mechanism of images.

- For acquiring the DICOM images (CT and the X-ray equipment) an application was designed with the Query/Retrieve and Storage services, acting as SCU (Service Class User). This application can acquire and store the images in the PACS.
- The images coming from digital radiology equipment, Agfa ADC SOLO (not DICOM), are acquired through the PACS already localized in the hospital radiology deparment (Agfa Impax MG 3000). This PACS stores the images in DICOM format.
- The RM (not DICOM) studies are acquired through a programmed FTP and transformed from its proprietary format to standard DICOM through a software developed for such aim.

The computers are automatically requested every 24 hours.

b) Database design

For the database, an Entity – Relationship model is designed and implemented following the data model defined in DICOM standard.

c) Interface development

The information that would be necessary to show, and the look of the Web pages was defined, as well as the basic functionalities.

d) Security mechanisms: user profiles and safe transmission of data

At this point, we determined which data are for public access and which for restricted access. In order to maintain the privacy of the data in the transmissions via Internet, it is necessary to use a safe protocol.

e) Advanced visualizer

The visualizer JAVA developed allows to access to this source of images and to apply different digital processing techniques to them, as well as to make available an amount of tools to the user that can help in obtaining a more precise diagnose. Such possibilities are: filtrate of images, outlined, smoothed, pseudocolor, equalization, brightness and contrast levels adjust, etc.

III. RESULTS

a) Structure of the Information Server

When a Internet accessible medical information system is designed, it is necessary to define which zones are for public access and which for restricted only (table I).

Taking advantage of the great amount of stored medical images in the system, a zone for public access has been defined and we have called it “gallery of images”. In this gallery, created with educational aims, the images that the radiologists consider of interest for being exposed publicly can be consulted. Naturally, these images are anonymous. The access to the gallery of images can be done by different criteria: by modalities, pathologies or anatomical zones.

With respect to the secure zone, each user must identify by means of login and password. From this point, the system assigns privileges to the opened session to accede to some or all funtionalities.

In table II the different levels of access to the system are represented

Once the user identifies itself and its level of privileges is obtained, he can accede to the images by means of different criteria. The user can directly consult all those studies that he has asked for, which facilitates the habitual accesses enormously. When a radiologist accedes to a study, is possible to make the radiological report online or to consult the data that have been already made by other colleagues (whenever he has the necessary privileges).

b) The DICOM files are stored in the database like data of type BLOB (Binary Large Object), so respecting the standard format.

The transmission through Internet is slow due to the great size of the data. With the purpose of reducing the amount of data we have to transmit, an icon of fast visualization (preview) for each image is generated in JPG format (around 50 Kb). Furthermore, each study is associated to the “preview” of the first image that composes it. These icons allow the specialist to have one first fast vision of the study in order to select a concrete image to be analyzed and/or reported. Once the study is selected, all the images that compose it are shown. This is the moment when an original DICOM image (of big size) is acceded and visualized.

TABLE I
IS SCHEME

Public access: gallery of images		
Search by modality		
Search by pathology		
Search by anatomic zone		
Images list		
	Usual images	
	Pathological images	Diagnosis consult
Restricted access: medical assistance		
Search by CHN		
Search by patient name		
Search by doctor and date		
Search by modality		
Own images		
Advanced search		
	Reports consult	
	Reports edition	
Management		
Users and profiles management		
Access log consult		
Table management		
Work statistics		
Web server management		

TABLE II
USER PROFILES

Profile	Functionalities
Guest	Images and information of all the images consult (gallery of images and pathological images) but without personal data
Doctor	Clinical cases and private reports consult with patients data
Specialist	Studies consult and complete access to reports: creation, consults, edition and drop
STAFF	Access to all the system: clinical private zone and web administration of the system

c) Volume of data

The load of images generated by the service of Radiology in all modalities acquired by the SINFIM in the Modelo Hospital are detailed in table III.

TABLE III
VOLUME OF DATA

Modality	Images/ study	Studies/ day	Image size (MB)	Volume/day (MB)
RMN	80	10	2	1.600
TAC	40	15	1	300
Rx	1	100	8	800
Remote X-ray system	45	8	3	1080
	Totals	133		3780

TABLE IV
SYSTEM PERFORMANCE

Number of images	Response time (seconds)
3200	1
6400	4
9600	10

d) Tests of system load: They were made a tests series of performance and response time of the system. For that reason, the system was tested with the amount of information that would be stored in 1, 2 and 3 months. Once loaded the images consults with a selection of 10 studies were made with acceptable response times. These results can be seen in table IV. The access to the Web server was made in the Intranet of the hospital, that uses fast Ethernet (100 Mbts/sg) technology and with access to Web secure pages (SSL) [18].

e) Implementation of security mechanisms

The developed system allows to define user profiles and to store them in a MySQL database. On the basis of these profiles the access to the PACS is controlled: when a user tries to access to the PACS, this one is asked for his username and password: if it is a valid user, his profile is recovered from the database (options, preferences, privileges...).

The data are transmitted via Internet using SSL protocol (Secure Sockets Layer), that guarantees the data privacy and integrity, as well as the identity of the Web server.

IV. DISCUSSION

The demand of information, from internal sources and the external ones in the majority of installations happens once implanted the PACS. Using Web technology, the answer to these demands has an easy solution.

The system is developed with low cost tools: PC hardware and freeware software. Our system works with a more than acceptable performance in the center we choose for implantation. In bigger hospitals, it would be necessary to employ commercial tools, that guarantee reasonable response times independently of the work load, concurrent access of a great number of users and fault tolerant hardware.

Constant growth: The requirements of storage of the PACS will increase indefinitely. It is necessary to design a mechanism which allows to restore the already stored digital medical images in low cost storage systems (DLT, DDS4, etc.).

The PACs installed in most of the hospitals are proprietary systems, developed by only one company. These systems are closed, not allowing to develop applications on them. Although the tendency is the DICOM standardization, at the moment there are a multitude of compatibility problems. The SINFIM is a system completely modular and escalable. It is possible to change each one of the components of individual form (the DBMS, the Web server or the Web-DB gateway) without affecting the rest of the components.

V. CONCLUSION

PACS and Teleradiology systems will determine the difference between being competitive and "to be up-to-date" for many institutions.

A PACS is not a sum of interconnected equipment, but more like medium, a concept of exchange of information based on images and data between doctors, services and hospitals. It is a concept of integration between the hospital information and the world of the global communication.

The possibility of acceding to the radiological studies from any computer connected to Internet is available for the radiologist. This allows a doctor to be on call without being physically in the hospital. With the new generation of wireless telephony (UMTS) it will be even possible to make the radiological reports from any place, without the need of a computer.

Levels of access security to the data and a communication protocol that guarantees the transmission of the data of safe form, according to what is demanded by the effective legislation in Spain [19] [20] have been configured.

It is a system of easy use and low cost, operating and with automatic acquisition of DICOM modalities. Used tools are freeware, with spread use in Internet and great number of examples of servers.

REFERENCES

[1] MA. Martínez, AJR. Jiménez, BV. Medina, LJ. Azpiroz. "Los Sistemas PACS". [Last access 08/12/2000]. Available *URL http://itzamna.uam.mx/alfonso/pacs.html*

[2] SL. Lou, Hoogstrate, HK Huang. "Automated PACS image adquisition and recovery scheme for image integrity based on the DICOM standard". Comput Med Imag Graph 1997;21:209.

[3] "DICOM Standard Status. Base Standard access 05/28/2001] Available URL: *http://www.dclunie.com/dicom-status/status.html*

[4] J. Fernandez-Bayo, O. Barbero, C. Rubies, M. Sentis, L. Donoso. "Distributing medical images with internet technologies: a DICOM web server and a DICOM java viewer". Radiographics. 2000 Mar-Apr;20(2):581-90.

[5] E. Setti, R. Musumeci. "A visual displayer for publishing radiologic images on the World Wide Web". Radiol Med (Torino). 2000 May;99(5):383-7.

[6] F. Terrier. "Web and PACS: heralding the new age of imaging in the health care community". Abdom Imaging. 2000 Jul-Aug;25(4):331-2.

[7] R. McColl, T. Lane. "The DICOM-WWW gateway: Implementation, configuration, securuty nad privacy". [Last access 01/04/2001]. Available URL: *http://www.rad.swmed.edu/PhysWeb/dicom.htm.*

[8] GJ. Grevera, E. Feingold, SC. Horii. "A WWW to DICOM interface". [Last access 01/04/2001]. Available URL: *http://oasis.rad.upenn.edu/~grevera/papers/spie/mi96/www.paper.html*

[9] "AGFA PACS". [Last access 01/04/2001]. Available URL: *http://www.agfa.com/healthcare/en/showtext.t3l?file=pacs_market.html*

[10] "PACSpage: Industry Vendors: Web-based Solutions". [Last access 01/04/2001]. Available URL: *http://www.dejarnette.com/efinegan/ppv_web.htm*

[11] L. Beird. "Bringing all modalities online: A PACS success story. Applied Radiology". Socioeconomics of imaging. Dec. 1999. [Last access 01/04/2001]. Available URL: *http://www.appliedradiology.com.*

[12] GM. Kolodny, S. Mitchell, JA. Parker, KJ. Donohoe, L. Barbaras, D. Jansons et. al. "Cost Savings in a Digital Radiology Department". [Last access 05/28/2001]. Available URL: *http://ej.rsna.org/EJ_0_96/0051-97.fin/Pacs97.html*

[13] B. Parker. "Estudio de un caso de implantación de [Last access 05/25/2001]. Available URL: *http://www.vcgimagen.com.ar./EspPACS3.htm*

[14] "Apache secured by SSL" [Last access 05/26/2001]. Available URL: *http://www.apache-ssl.org/*

[15] "The Netcraft Web Server Survey" [Last access 05/28/2001]. Available URL: *http://www.netcraft.com/survey/*

[16] "MySQL official home page" [Last access 05/01/2001]. Available URL: *http://mysql.com/*

[17] S. Sather, A. Aulbach, E. Schmid, J. Winstead, T. Torben, R. Lerdorf et. al. "PHP Manual" [Last access 02/05/2001]. Available URL: *http://www.php.net/manual/*

[18] "OpenSSL official home page" [Last access 04/15/2001]. Available URL: *http://www.openssl.org/*

[19] "Ley Orgánica 15/1999, de 13 de diciembre, de Protección de Datos de Carácter Personal" (Boletín Oficial del Estado, número 298, de 14 de diciembre de 1999)

[20] "Real Decreto 994/1999, de 11 de junio, por el que se aprueba el Reglamento de medidas de seguridad de los ficheros automatizados que contengan datos de carácter personal" (Boletín Oficial del Estado, número 151, de 25 de junio de 1999)